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## **1987 Ship Production Symposium**

### **Paper No. 27: Shop and Zone Administration and Management: The Transitions to Zone Outfitting in Repair and Overhaul at Puget Sound Naval S.Y.**

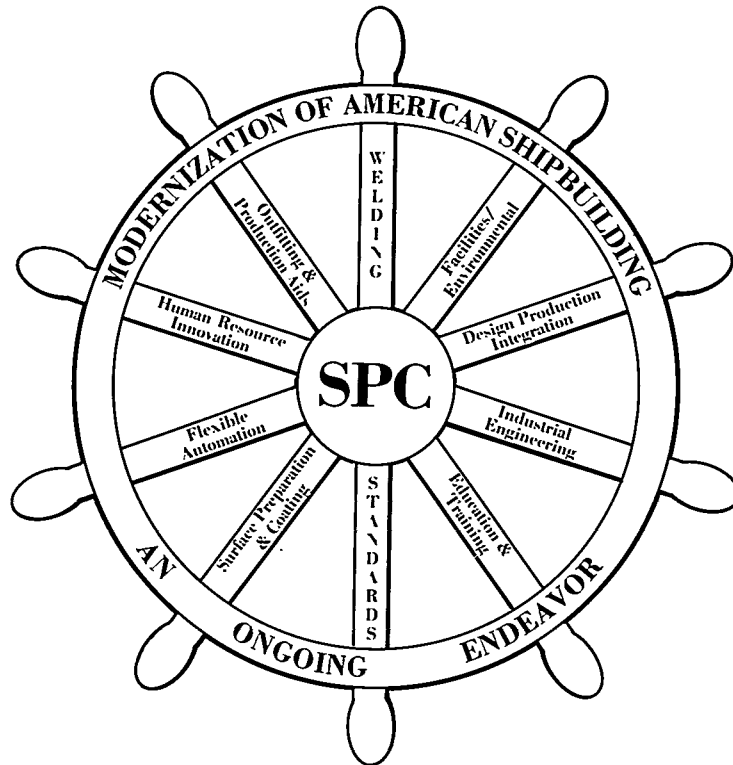
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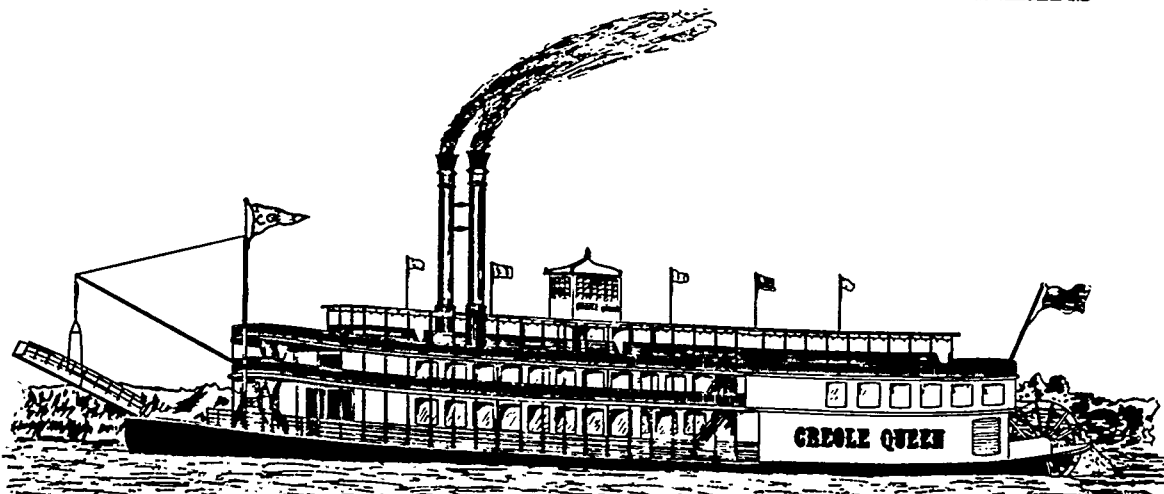
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# **Shop and Zone Administration and Management: No. 27**

## **The Transitions to Zone Outfitting in Repair and Overhaul at Puget Sound Naval Shipyard**

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### ABSTRACT

This paper discusses Puget Sound Naval Shipyard's implementation of Zone Outfitting in Repair and Overhaul (ZORO). Four problems are responsible for past poor performance: funding by system, planning using key-operations which are too broad, scheduling by event, and inflating cost by inaccurate historical expenditure records. These problems are discussed and addressed.

To solve the interactive problems, a new product management structure is being examined. The system is based on a Project team called an Outfit planning Group. Using composites, facilitated by a CAD model, this team of people is responsible for packaging and sequencing the work. The result is a sequenced work package that is scheduled in an incremental time line to support work to be accomplished.

The Work Packages are composed of Unit Work Procedures -- stand-alone information packages. The Unit Work Procedure facilitates schedule enhancement, manhour estimating and manning, and aids in palletization, inventory, and delivery of materials to work centers. Four standard groups of unit work procedures have been established: (1) fabrication, (2) assembly, (3) installation and (4) repair.

The present system-oriented Management Information System (MIS) is unable to process information that crosses Ship Work List Item Numbers (SWLINS) and key-operations, a necessity in zone planning. Suggested changes in the MIS will allow funding, packaging, sequencing, and scheduling to be accomplished independently of one another.

Several preliminary studies have also been released which show significant gains as a result of ZORO. A study of manhour comparisons between identical work, prior to the use of work packaging and after, shows a decrease of thirty percent. Comparison of the manhours required for planning versus manhours

saved shows a savings of fifty-four percent. Although these results are very preliminary, they indicate an extensive potential for improvement in both efficiency of production and effectiveness of work packaging.

### THE PROBLEM

Over the last ten years, there has been a consistent effort by our maritime industrial base, through the National Shipbuilding Research Program (NSRP), to identify positive applications to resolve the problems which have caused the U.S. shipbuilding industry to fall so far behind in the international marketplace. A few U.S. shipyards have incorporated these studies and have successfully turned the corner. Naval shipyards, as a whole, are seeing a large challenge to change their methods of conducting life cycle support and to implement these progressive applications in order to lower their costs.

The solution to increasing the Naval shipyards' effectiveness begins with understanding the basic problems inherent in the present system. The very heart of the Naval shipyards' problem is an annual budgeting system.

Every year a specific dollar allotment is given to the U.S. Navy for maintenance of the fleet. In turn, based on the amount of work in each of the eight Naval shipyards, the budget is proportionately divided to cover the estimated expenditures. Money not expended or not anticipated to be spent during a fiscal year is returned. The returned funds are then redistributed to cover under-estimated expenditures in other Naval shipyards. Any money which is unspent dissolves at the end of the fiscal year. On the surface this may seem to be an efficient distribution of the budget. This is not the case.

The system establishes the rule: what you don't spend, you don't get. Thus, the system discourages anyone from saving money. Private industry turns saved money into profit for share-

holders, research, and equipment investment. No such incentive exists within the government structure. Without profits to fund investment, the shipyards are encouraged to continue overexpenditures. While the production facilities become antiquated, both in equipment and method (Figure 1).

Within the Naval shipyards' system there is a strong desire to become competitive: to change the numerous internal problems which result from government regulation [1]: and to modernize facilities, equipment, and methods. Based on published documentation of the National Shipbuilding Research Program [2]. Puget Sound Naval Shipyard is implementing Zone Outfitting in Repair and Overhaul (ZORO) [3].

To effectively implement any program, a feedback loop is necessary in order to identify problems and judge improvements. The shipyard MIS, the cost tracking program presently used in the Naval shipyards to provide feedback, cannot do this at this time [4]. The present way work is planned and scheduled indicates a need to adjust the MIS system to more effectively and flexibly provide information for management.

The assignment of work is given to the shipyard under a SWLIN, which indicates work on a system, either the repair of old equipment or the installation of new. The work within a SWLIN is then divided into job orders, which are further divided into key operations or key-ops. The job orders are phased depending on the work in the key-op. (This is tied to the ship work breakdown structure, SWBS.)

The key-op is the document which defines and funds the work. It contains a number of tasks which vary from a few manhours of work to thousands of manhours. The key-op document gives brief descriptions of tasks: references other drawings, specifications instructions. and/or publications that need to be accomplished: and identifies which shop (work centers) would be performing the tasks.

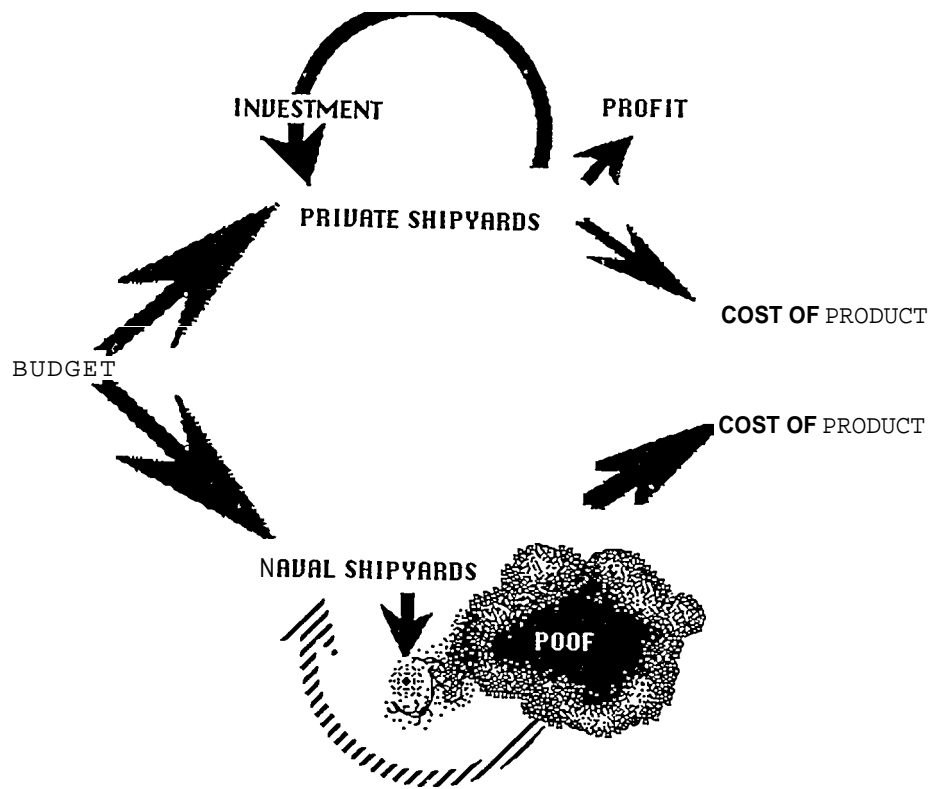
The MIS is used to track cost accumulations of key-ops and to store the costs to estimate similar work on another vessel. The key-op is vulnerable to mischarging. and when inaccurate charging is entered into the MIS, future work estimations will be incorrect. The key-op is vulnerable for a number of reasons. First, it is multi-tasked, usually containing thousands of manhours of work [5]. The key-op cannot close until all of the tasks are complete. and often remains open for an extended period. Research time is not part of the allotment of

manhours given to a key-op, but larger jobs require research and the key-op's funds are used to pay the mechanic while he performs the necessary research.

Several jobs are worked by the mechanic daily. He may spend only portions of an hour on one or two and the rest of the day on a third. It is inconvenient to report small portions of work and commonly one job order would be reported. On occasion, work is not available for all the mechanics on a shift. Two choices are open to the foreman: he can call around to see if another job is short of mechanics. or he can double up on some of the work. A third option exists -- to pay the extra mechanics on shop overhead. but this action reflects badly on the managerial ability of the foreman, and is perceived to be frowned upon by management. Because the shipyard maintains a constant manning force, the situation can arise often. Therefore, job orders which could be closed are left open to ensure that the foreman has a reserve to pay his people. These practices are necessary for a foreman to successfully pay his work force and maintain a good record. It also ensures that almost every job order uses all the funds it has been budgeted.

The system encourages mischarging by creating a key-op which is too broad. and which remains open to be charged against. The inability of the foreman to control the size of his work force or his accessibility to his assigned tasks causes him, on occasion, to mischarge in order to pay his people. Research time is a significant portion of work which is not accounted for, but is appropriately mischarged to the job which is being researched. The MIS easily hides much of this mischarging. It keeps a record of who charged against that key-op and the total amount spent at a work center. On a large job it may be unclear who has worked it and who has not. Many different tasks are performed at some work centers (especially inside the shop), so it is uncertain who mischarged and by how much. The key-ops are now on record as having been estimated correctly when job orders are closed with no funds remaining. and underestimated for key-ops which have overexpended their allotted budget.

New key-ops are written against this historical data to estimate the time required to do the work. In the case above, both jobs appear to reflect a correct record of the cost of a key-op: that same amount of time is again allotted, plus a margin to allow for unexpected growth. In a continuous cycle, the time required continues to inflate. This trend has been documented (Figure 2).



**FIGURE 1**

Naval Shipyards would benefit from a reinvestment loop (dotted arrow) which Would allow the shipyards to modernize their facilities and encourage savings.

REAL WORK AS PERCENTAGE  
OF EXPENDITURE  
(HYPOTHETICAL EXAMPLE)

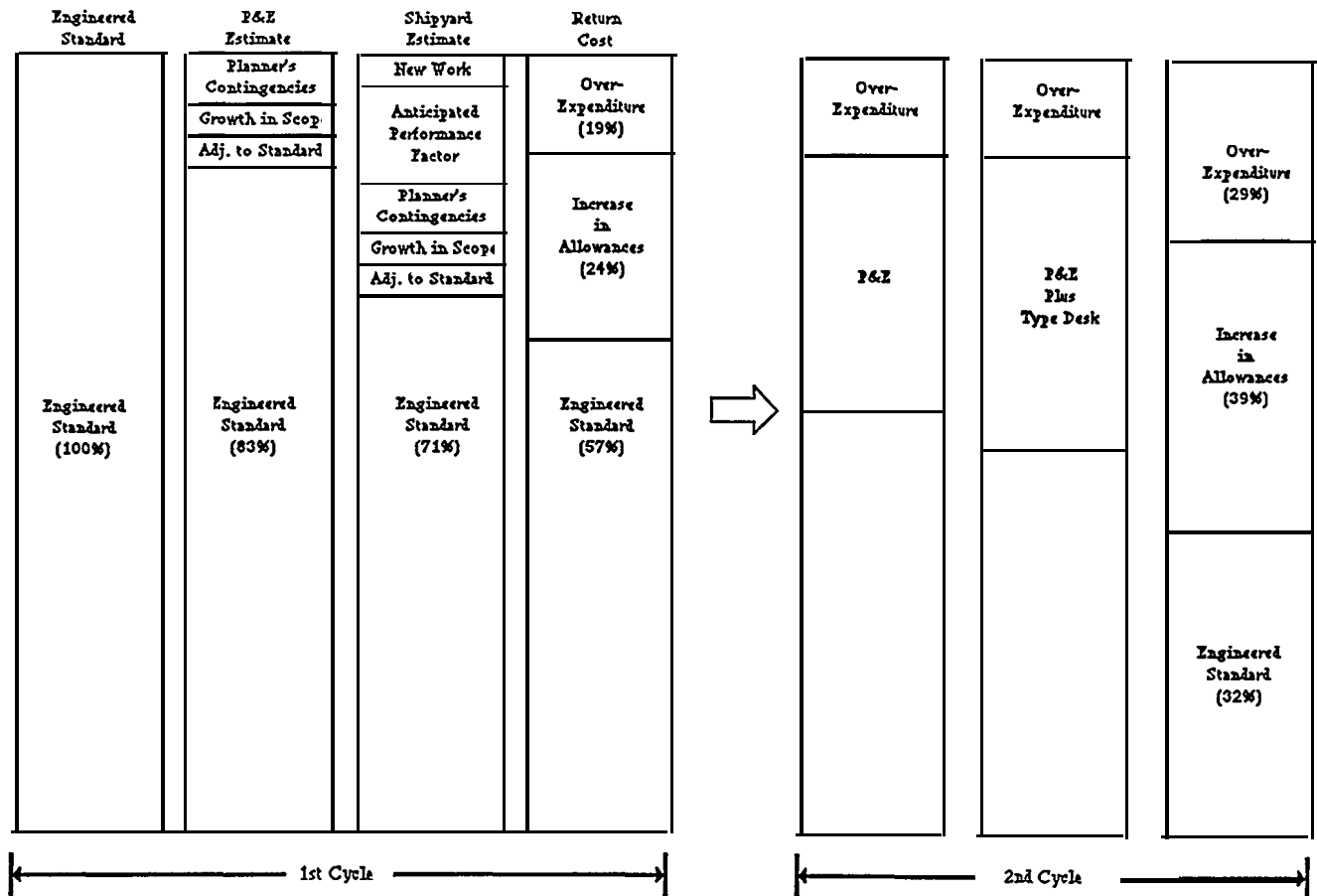


FIGURE 2

In Cooper and Lybrand's Report on the Naval ShipyardS the continual inflation of the key-op was documented. The multi-tasked key-op remains open for an extended period which subjects it to rnischanging.

The system of scheduling the key-op produces problems which can delay Production work. Once a job order is divided into multi-tasked key-ops and phased, a schedule is developed, tying key-ops to key events. A key event is a group of key-ops in the overhaul which must be accomplished by a certain completion date to continue subsequent work. All key-ops in an event have the same completion date. Often work which must precede other work is given the same completion date. Work on one system often interferes with work on another. Drawings, developed by system, are not easily checked for interferences. Systems are often close together, preventing more than one system from being worked at a time. Mechanics are left with the responsibility of identifying interferences and working out a schedule among themselves.

If one system interferes with another and each has a different completion date, the interference can cause the system with the earlier completion date to finish behind schedule. No means in the system, beyond the memory of the scheduler, can anticipate these problems.

Problems in planning and sequencing are usually handled when they are discovered by the mechanic on the ship. The mechanic is burdened with gathering the numerous references (and references on the references) within the key-op before he can establish what he has to do. Planned correctly, the research data should be provided to the mechanic.

This leaves us with five inter-active problems. The first is that funding establishes a system prone to



waste. This problem is not within the bounds of the shipyards' control: however, it can be significantly reduced by correcting the remaining four. The four remaining problems are: the interactive traps of funding by system, planning using key-ops which are too broad, scheduling by event, and inflating cost by inaccurate historical expenditure records. All four of these problems must be tackled together for any solution to be effective.

#### CRITERIA FOR A SOLUTION

To construct a solution, certain criteria have been established that will better direct and evaluate progress.

1. Communication between Production, Engineering, Planning and Estimating, Scheduling, and Supply will support a product work breakdown structure.
2. A method of planning and scheduling should be established to facilitate build strategy development and work sequence, developed by zone/ stage rather than system to account for impacts within a work parameter [6].
3. Information delivered to the mechanic should contain all the information required to accomplish the work, enabling him to quickly understand the scope of the work and begin.
4. The MIS must be adjusted to enable analysis of work by relating manhours expended to physical characteristics of material, e.g. length of gas-cutting during ripout, weight of pipe pieces assembled on board, lengths of electric cable pulled in place, etc. Work so classified by problem category (area) and such description of how work is normally being performed permits the employment of statistical control methods and realistic manhour budgeting and scheduling. This implies redefining the tasks, processes (manufacturing, ripout, assembly, installation, etc.) and work centers.

These criteria will be used to judge the ZORO program currently underway at Puget Sound Naval Shipyard.

#### THE OUTFIT PLANNING GROUP (OPG)

The present Naval Shipyard planning system is dominated by a system-oriented approach. This approach stems directly

from work assigned on the budgeting level by system; work receives funding through system drawings and key-ops. Unfortunately, this has resulted in planning, production, and design being divided into separate entities concerned with their own responsibilities and having limited interface between these organizations.

To support a product-oriented approach, a team of people collectively knowledgeable in all the tasks involved was perceived as the best means to plan the work. The OPG was the result.

The OPG, in effect an ad-hoc product team, is a medium for communication to produce and schedule a strategy which melds production, planning, and design engineering. Using the zone/stage concept, an OPG is responsible for the development, planning, and execution of a Project leading to a specific product, e.g., outfitted and painted block, overhauled submarine ballast tank, etc.

The OPG's are overseen by a steering committee. The steering committee is responsible for analyzing and evaluating current and future ZORO projects. It also directs and coordinates the ongoing ZORO program, dealing with resource use, equipment acquisition, the distribution of ideas, and recommendations to management to adjust personnel requirements. The steering committee is composed of management facilitators from both the Production Department and the Design Division.

Each OPG is co-chaired by one representative from design and one representative from production. The design chairman is in charge of preparing composite drawings that reflect the build strategy mutually conceived with the production chairman. The production chairman is responsible for manufacturing components and assembly work per the built strategy. Both share responsibilities for breaking the project into sequenced stages, and, for their respective areas, are responsible for budgeting manhours and for scheduling. The co-chairmen are selected by management, based on their expertise, commensurate with the problems posed by a specific product assigned.

Titles given to the design and production representatives are Chairman and Zone Manager, respectively, as they have major responsibilities in accomplishing work associated with the product assigned. The OPG itself is composed of two groups, the core group and a support group.

Typically, the core group is composed of the Chairman representing engineering, the Zone Manager representing the lead production shop,

as well as representatives from other important production shops, critical support shops (such as testing), scheduling, supply, planning and estimating. Mechanics, experts on the strengths and limitations of production, now have direct input into how work is accomplished.

A support group is also chosen from those who have a limited role in the completion of the project. Together, this team of people is responsible for packaging and sequencing the work (Figure 3).

#### PACKAGING AND SEQUENCING

The projects to be planned generally comprise a piece of the ship. These large regions are referred to as grand zones. To facilitate the completion of the project, the OPG reduces the grand zone into individual zones. These zones are then extracted from a CAD model in the form of three dimensional (3-D) graphics, to be used as an aid in planning and sequencing the work. These isometrics are a composite of various systems and ship-alts found within the zone.

To assemble the model at this time is the most expensive portion of the ZORO process. It involves an intense amount of CAD computer and operator time. The structural loft is presently the major modeling unit, with representatives from the sheet metal, electrical/electronics, and pipe shops also participating. In the future, modeling will be accomplished by engineering or a trained contractor. Future alterations to the vessels can be designed on the model and the stored data transferred to the production facility to be planned in detail for production (Figure 4).

In constructing the computer model, several steps are followed to allow easy access to the model and ease of expansion at a later time. The first step is to enter the frames and external structures. Next, the model is filled with existing structure, deck modifications, and new foundations (Figure 5). Also entered are piping, electrical, and ventilation systems. Each model entity is "built" by the respective production shop which usually handles the respective installation. The shops are organized around a layering scheme. Using this layering scheme, the model entities are stored as a unit and can be viewed separately, or combined with other systems from the other shops. Once this is done, the entire model is assembled and a checking process has begun. As the layering is by types of work, it represents inclusion of production planning before the design is issued to the mechanic. This is a singu-

lar difference. Traditionally, planning is accomplished after the fact, and problems are solved onboard using costly amounts of time and rework.

The model is examined to find any interferences between planned and existing structure or fixtures. The model is updated based on ship check information, and advance notice of drawing changes. The mistakes that surface are studied, and solution proposals are developed and discussed with the planning organization - usually the Expanded Planning Yard (EPY) [7]. Any problems encountered are illustrated with graphics from the CAD and are then forwarded to the EPY to officially incorporate the changes.

In the past, these shipboard configuration problems did not surface until the installation phase was being accomplished onboard the ship. Each problem found required 5 to 15 days to resolve, delaying work considerably.

Drawing changes result in more serious problems, but with zone-oriented logic, which features planning before the fact, changes are greatly minimized.

In the traditional system-by-system approach, even when CAD is employed, problems often occur because drawings issued to the waterfront are already several revisions behind. Drawings, once updated by the EPY, take one to two months to reach the waterfront of the overhaul yard. This time period is often enough for the overhaul yard to complete the work which has been changed on a revision. When the new revision arrives, P&E funds "rework" to correct the designed-in work (in other words, they do the job right twice). Advanced Notice of Drawing Changes (ANDC) are issued much faster than the drawings themselves, often arriving a month or more ahead of the drawing. The ANDC contains the change which will be made to the drawing [8]. By correcting the model, and the work graphics created from it, the rework can be reduced to minimum levels.

Every piece in the model is given intelligence. It is connected to a database containing information about that part. At present, the information stored is reflected by the output shown (Figure 6). This information is presently used to create material lists giving an upfront view of material to the shop planners, regardless of job order or key-op. The planners use these material lists to accomplish material ordering and assembly instructions, and to provide a material checklist for the mechanics. In the future, material staging and ordering will be supported by the model piece database.

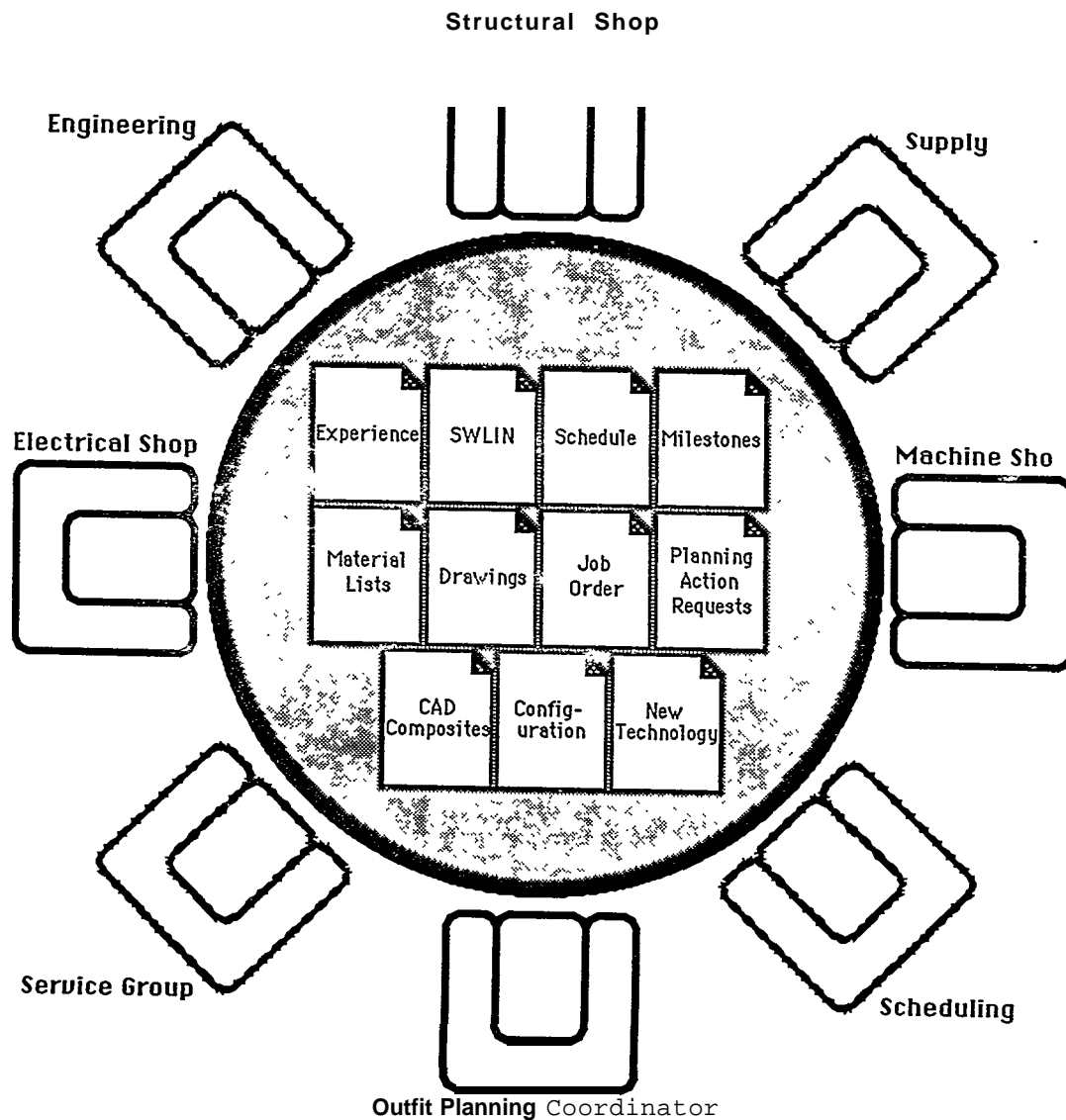


Figure 3.

The Outfit Planning Group provides the opportunity for the collective experience of the members and all the information available to package and sequence the work. New methods, technologies, and innovations can readily be considered and introduced into shipyard procedures.

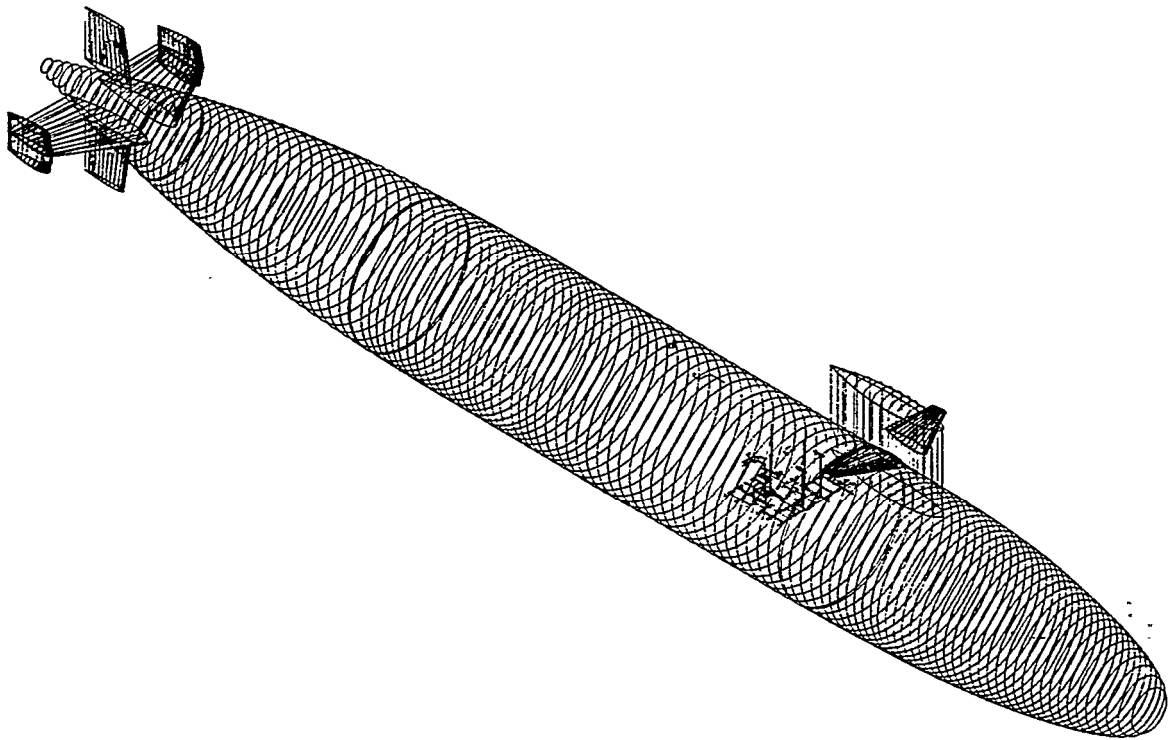


FIGURE 4

The hull of the model is defined and then the structure is inserted followed by foundations, piping, and venting. Above is shown a zone inside the hull frame.

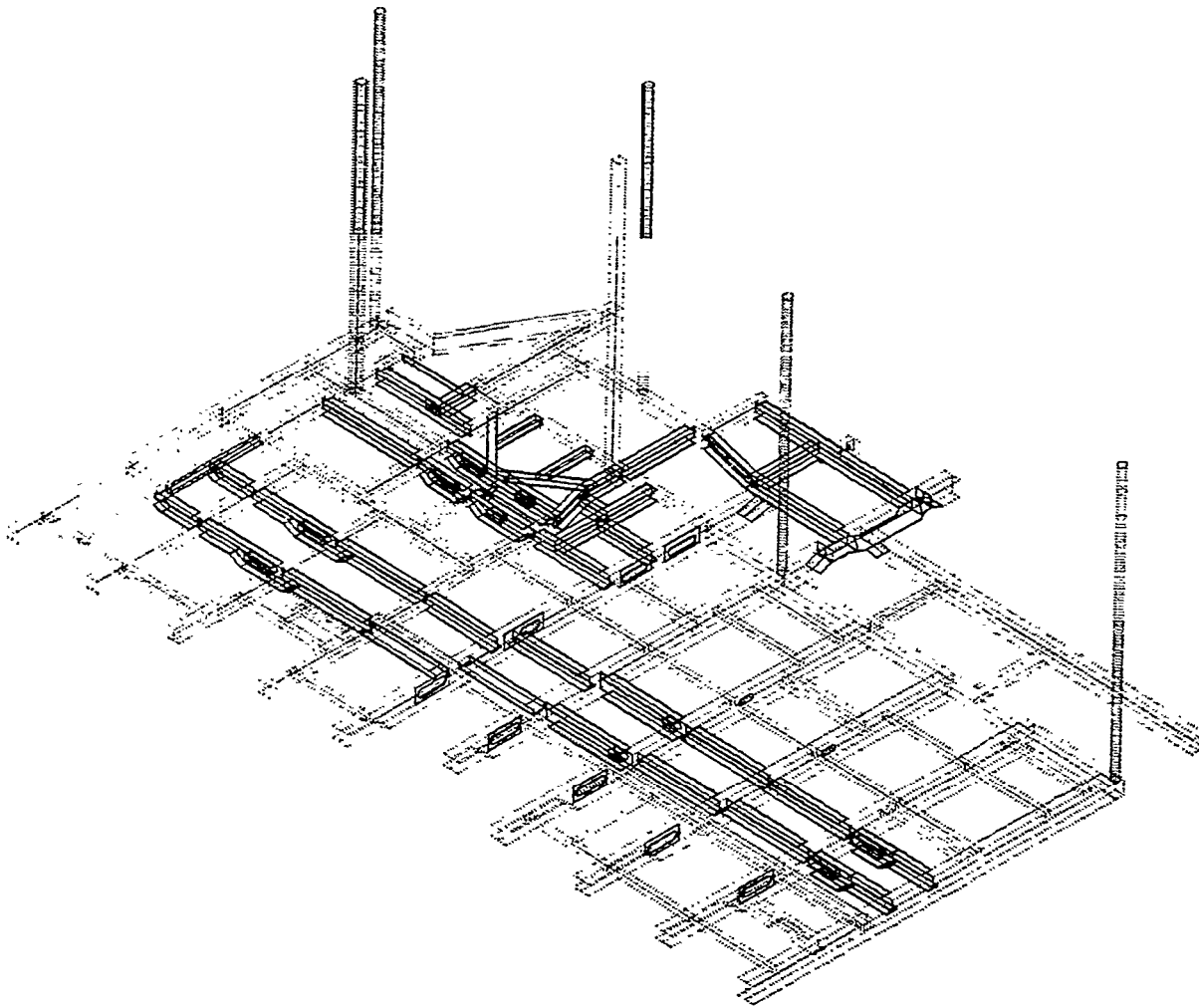
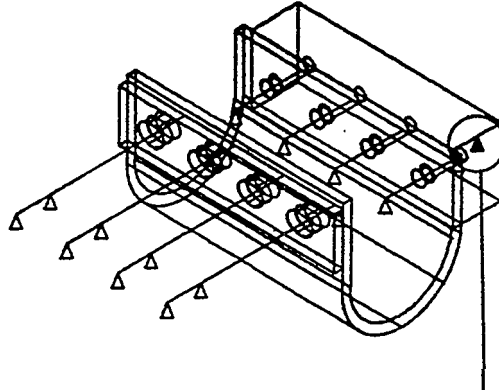


FIGURE 5

The existing structure is faded to avoid confusion in examining the composite. The figure above is the deck ripout in a zone. The ripout composite is a combination of ripout and installation drawings from a number of different ship alterations. In the past it was up to the mechanic to assemble what needed to be ripped out.



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FIGURE 6

Each piece is tied to a material database which contains specific information about that piece. This database is used to order material, create assembly instructions, and as a check list for the mechanic on the boat.

Material paybacks alone will justify extensive modeling of ships.

The model is used to generate graphics of each zone (Figure 7). These isometric views are used by the OPG to develop the build strategy. Unlike the system drawings, the views offer several important advantages.

The isometric clearly illustrates how work on one unit will impact another. The flow of work becomes much clearer with all units shown together. The isometric also allows like processes to be identified and grouped together. The most interesting effect, however, has been the new ideas generated by looking at these foundations together as a unit. This has led to combining foundations, reducing weight and volume, and to performing more assembly work in shops.

Once the OPG has discussed the work, the group divides the work into work units (groups of foundations, piping, etc.). The work throughout the zone is then considered in terms of work package phases (Figure 8) and sequenced accordingly. The result is a sequenced work package that is scheduled in an incremental time line to support work to be accomplished. This significantly reduces rework caused by interference with unknown work on another system, and speeds up work, streamlining the production process. It identifies the manning requirements, thereby avoiding two jobs being assigned in the same space at the same time or not having support trades to accomplish assigned work. Further, work so modularized and classified by problem area, per group technology logic, clearly identifies work circumstances that are sufficiently predictable to be controlled by statistical methods.

The Zone Manager and Zone Chairman then take the proposed schedule and assign unit work procedure numbers (Figure 9). These numbers indicate the location task, and sequence of the work unit. The CAD group then begins the production of the Zone Work Packages and Unit Work Procedures.

#### UNIT WORK PROCEDURES (UWP)

The Unit Work Procedure [9] is a stand-alone information document, containing graphics and text, material requirements, and listing any special tools required to accomplish the task. The UWP is a permanent record of work to be completed -- tied to funding and to schedule. Work progress and cost can be tracked directly from the UWP. The UWP relieves the mechanic of the task of researching and interpreting the key-OP's references and work descriptions. Johnny Risko, a mechanic commenting in

the installer's notes at the end of the UWP, wrote, "These unit work procedures are a real time saver, and make the job go faster with more ease. I spent no time having to run down drawings that were not at hand. Everything was at my fingertips. I LIKE THIS IDEA!" In general, the UWP has been enthusiastically received by the mechanics. Four standard groups of UWP have been established: (1) fabrication. (2) assembly. (3) installation, and (4) repair.

The fabrication UWP are divided into subgroups depending on the fabrication process: cuts and forms for structural, cut and bend for piping, and cut and brake for venting and electrical cable lengths. The UWP within a subgroup support a particular type and size of material within a single zone. Staging direction is also included to direct the pieces for assembly by zone.

Movement of each piece is tracked in the pipe shop by a bar coding system. The bar code of each piece is entered as it arrives and when it departs from a work station. At any time, the progress of any piece can be checked by seeing where it is within the shop. Programs to sort and analyze this information can report problem pieces or inform the next work station that it has all the pieces necessary to continue work. The bar coding system has proven effective in tracking work in the pipe shop and will be expanded to other shops. At this time, the yard intends to premanufacture all pieces and assemblies prior to a ship's arrival. As material receiving and tracking improve, a just-in-time system is anticipated to facilitate better use of staging areas and smooth in-shop work load [10]. Manufacturing or overhauling components in shops long before they are needed is not generally understood to seriously detract from productivity. But even if they did understand, traditional system-by-system planners do not give shops adequate knowledge of when components such as manufactured pipe pieces or overhauled valves are needed for assembly work. The schedule for zone/stage work packages and their material lists solves this problem.

The assembly UWP provides text and graphics to assemble the pieces into a unit. The bar code system will allow easy assessment of the material to confirm whether all the pieces are present. The graphics will include a 3-D isometric of the completed unit. This will give the mechanic a good idea of what the unit will look like, reducing errors that result from misinterpreting a drawing. Assemblies may include more than one shop's work. A foundation may be assembled, drilled and tapped: a component set in place: and piping and

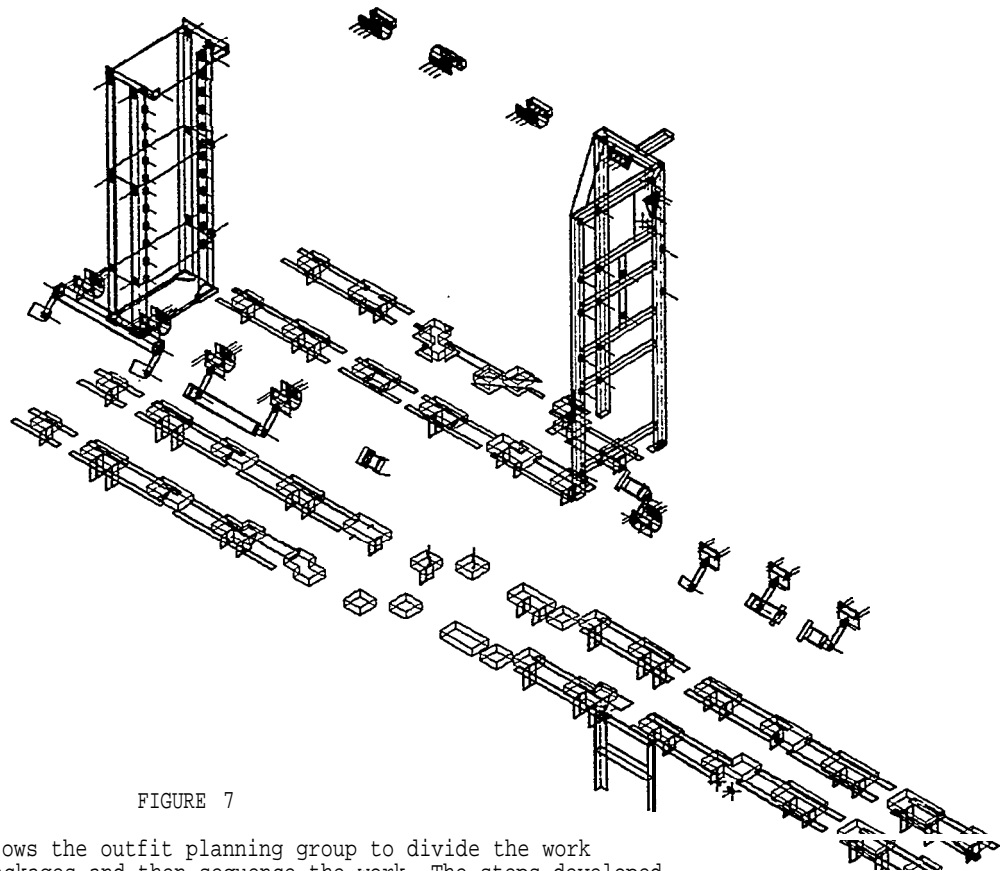


FIGURE 7

The composite allows the outfit planning group to divide the work in a zone into packages and then sequence the work. The steps developed are then assembled into unit work guides.

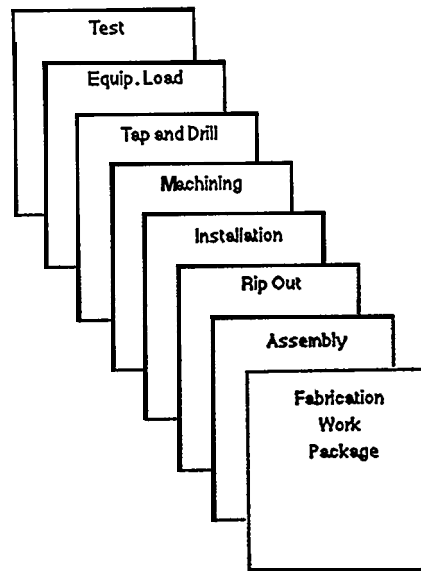


FIGURE 8

Work Packages contain Work for all trades in a single zone. The Work package is composed of unit work guides, sequenced to accomplish the phase of the work package with maximum efficiency.





wiring connected to match. The assembly is, itself, bar coded and staged to support zone installation when the vessel arrives. By increasing the use of assemblies, more work is accomplished indoors where the working environment is dry, Well lighted. and ventilated. Tools and materials are also much closer, and working conditions are safer [11]. Also, manhours, including those for painting. are more evenly distributed over an entire overhauling period.

The installation UWP are sequenced inside of work packages. Each work package covers a phase: shoring, rip-out, deck modification, installation prior to equipment onload, machining, installation after equipment onload, deck refurbishment, and test. Each work package contains installation work for every trade in its phase. The UWP are sequenced to ensure that work in the zone progresses smoothly. Some UWP can be worked in parallel, and this is noted on the schedule included in the work package [12]. The UWP themselves consist of a key isometric showing the area to be worked, sketches showing the work in detail, a cover sheet containing written information, and a list of loose pieces and assemblies. Also included are any procedures or documents necessary to complete the work. A sheet is included for comments by the installing mechanic, to provide feedback on the work accomplished.

The repair UWP contains prerequisite sites to be accomplished before work on a unit can begin, the paperwork necessary to document work performed (completed as much as possible before work begins), and a list of special tools and materials. coupled with graphics and text. The repair packages are supported by a loose sequence to support reinstallation and test. This flexible schedule helps to determine priorities of work, but still allows for flexibility. Growth is a certainty in repair work: often the complete scope of work cannot be known until the overhaul has begun. The OPG, knowing the scope of the work, can deliver a priority list to both the ship and the shop. The ship can then turn over systems in support of work which needs to begin first, and shops can work in the order necessary to support closing the job efficiently.

The most important advantage of UWP is that experience that formerly was vested only in individuals becomes corporate experience, also. Normal performance of each specific problem classification is published for all to consider. Dissemination of such information, supplemented by training the workforce in simple analysis techniques, e.g. Use of cause and effect and Pareto diagrams. makes for a constantly self-improving overhaul system through people working smarter, not harder [13].

Individual UWP are prepared by the shop completing the work in conjunction with Engineering. The sequence into which the UWP fits is developed by the OPG as a whole.

Each UWP is put together in a work package. The work packages contain the entire breakdown of work by everyone accomplishing work in that package. The work packages for each phase of the work comprise the sum of all work to be accomplished from inception to completion. Thus, all work is planned, sequenced, materially supported, and discretely available.

The work package also acts as a unique management tool. It provides a clear plan of work which must be accomplished, and the resources necessary to support that work. It is a unique progress tool, showing the amount of work complete. This ends the need for the foreman to look at the job, scratch his head, and guess a percent complete in discrete units of work. The work package also serves as a record of how work progressed, retaining mistakes and incorporating suggestions through both the zone manager's input and the installer's notes at the end of each work package and UWP, respectively.

The work package supports many process flow techniques. By combining similar work, statistical control methods can be used to monitor, control, and continuously improve shipbuilding design details and work methods so as to maximize production" [14]. This will be applicable not only to shop work; improved premanufacturing techniques and products will result in easy installation in the vessel, further increasing savings and quality.

Currently, tracking of the UWP is by manual batch (the mechanic affixing the time it took to accomplish the task right on the UWP). Certain adjustments to the MIS will be necessary to support the transition to ZORO.

#### MANAGEMENT INFORMATION SYSTEM ADJUSTMENTS

Presently, the MIS is used to accomplish three operations that need to be reevaluated. The MIS is used: (1) to record key-ops, which are written to represent phases of work. (2) to get back cost accumulation of charges, and (3) to aid in scheduling the key-op to an event.

The present phasing of work by key-op predetermines the work execution process (namely, how and what work is done and in what place), but accomplishes this with minimal transfer of information to the mechanic. The key-op is planned and scheduled using a narrow

scope, a particular system. (The mechanic cannot know how one key-op affects other work in the Phase. The mix of work, related or unrelated, has an impact: how can it be considered?) The OPG plans for the entire scope of the work. The work, however, must still be funded. Certainly, estimating will still be required to accomplish this task. Thus, a system is needed that will be flexible enough to estimate by system (at least for the near term) and support work execution by zone (product work breakdown structure).

Flexibility can only be achieved by enabling the internal elements of work (tasks) to be scheduled to an event. To do this, work must be broken down into functional steps. The use of functional steps will allow funding, packaging, sequencing, and scheduling to be accomplished independently of one another.

At present, daily expenditure reports are generated which show an accumulation of charges. What actually needs to be known is who spent the money: "who" being what portion of work or which task within the key-op. The present output of the daily key-op expenditure reports is the total which has been spent so far on any particular job order. To demonstrate how the system is giving inappropriate information, take the following example: within a fabrication key-op, a number of foundations are called out to be constructed. The planner accounts for 10 hours of drilling on each, giving the key-op (including cutting, layout, and assembly) a total of 400 hours. About the time 300 hours is spent, the foreman begins to get money conscious. Recognizing that he has reached that number of hours on his daily report for the key-op, he checks on the progress of the foundations. He finds that all have had their drilling completed, but half have yet to be assembled. He knows he does not have enough money left on the key-op to complete the foundations. He does not know who spent the money. Did cutting the pieces take longer than anticipated? Was the key-op inappropriately charged against to cover for extra manning? How could he tell? Further, the fact that 10 hours was estimated to drill each foundation is not recorded anywhere. The drillers may think they have 20 or 100.

To support future ZORO goals, the system must be revised to account for work at the task level, and this level be reflected accordingly in planning, scheduling and funding. The planner accounts for time for each task, each functional step. If that time is recorded, then through feedback the accuracy of that estimate can be determined. The actual time required can then be compared to what is normal for a particular

work classification. If the time required is below three standard deviations, then the classification of the work or the way it was performed is suspect. Investigate on would have to proceed accordingly. Identifying the functional step, and tracking cost by it, will give the foreman the management tool he needs to audit charging and determine percentage complete and work load.

Under the present system, when a key-op is scheduled, it is grouped with others to a key event which supports a completion date. The key-ops are phased when they are estimated and therefore are already scheduled -- ignoring the internal scheduling of the work within and between those key-ops. Alternatively, by allowing the OPG'S to develop work packages, sequences, and schedules (recognizing their internal interactions), work flow will speed up and cost expenditures will be reduced dramatically. To accomplish this, the funding of work must be made separate from packaging, sequencing, and scheduling work.

Problems seem to develop because the systems funding agent forces all work to be considered in terms of system alone. That funding agent describes the work inadequately, leaving the mechanics to develop a sequence. The funding agent influences the scheduling of the work, and because it is system-oriented, does not consider how work on one system impacts another. Funding by functional steps, using work packaging to sequence the work and scheduling to support them, minimizes these problems. Presently, changes are being considered to increase the recording and reporting capabilities of the MIS to support the functional step approach.

The recommended solution to adjusting the MIS is to begin by adding a few numbers to the already lengthy set. This change would not affect the processing time of data. To deliver the flexibility that is necessary, a redefinition of phases and work centers must occur (Figure 10).

The MIS would then estimate and fund the work, allowing the OPG to plan and sequence the details of the varied work of each trade, track the UWP (eliminating research time by the mechanic), record and report both method and cost by zone or system, and ensure accountability from the mechanic upward.

Ongoing projects currently receive funding and work assignment by key-op. They re-breakdown the work assigned using the work package concept. Once the work is accomplished, the feedback information generated from the UWFS and work packages is assembled and recorded.

## ACCOUNTING SYSTEM

```

Work Category
  Availability #
    SWBS
      SWBS Serial #
        Key-Op { Presently Phased By Work Center*
                  Shop Identifier (Organization)
                    Shop Work Center**
                      Subtask identifier***
                        Supervisor Code
                          Badge #of Mechanic

```

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\*Change accounting number to represent something portion of the ship/ components in an hierchical structured manner.  
 \*\*Change to task identity, phased and standardized across shops, functional steps. Add the ability to plan multiple similiar work tasks for work execution and get return costs at that level.  
 \*\*\*Add the ability to have shops indicate detailed planning by subdividing tasks, allowing the return of cost/ schedule data.

FIGURE 10

The incorporation of the proposed MIS system adjustments, both changes and additions(underlined), will create the ability to establish a relationship of tasks within a funding accounting number to a technical requirements file, indicating all the support, material, software, or resulting actions pending to accomplish the task.

To enable cost accounting, the time and material expenditures are reported back to the MIS in terms of the original key-op division. In the future, it is hoped that work will be developed by a product Work breakdown structure and assigned directly by zone.

To begin to integrate these new methods, several projects have been funded by Puget Sound Naval Shipyard. Already the program's early indicators point to dramatic cost savings in the future.

### PROJECT INDICATORS

Several ZORO projects are occurring concurrently at Puget Sound Naval Shipyard. In conjunction with Coopers and Lybrand (C&L), a series of studies are being conducted to help both PSNS and the Naval Industrial Fund Improvement effort evaluate the effectiveness of the outfit planning group, UWP, and zone planning.

The first of these studies is an evaluation of six completed ship alteration ripout packages from the biggest project [15]. A comparison was made of the charges for ripout on the present project using outfit planning and previous work on similar vessels before

outfit planning was applied. "The man-hours expended by the mechanic were accounted for. The preplanning involved a shipcheck, a revision to ripout drawings, sequencing of ripout work and the issue of revisions to drawings to the mechanic. The manhours charged to the project for the preplanning and ripout of foundation work indicates a savings of 295 manhours over the average 999 manhours charged previously" [16]. This significant savings in manhours, while an early indicator, "may not be a true indicator because it is a small portion of the work and CAD was not used" [17].

A second study was conducted to estimate the cost of a UWP. The work package chosen for study was the shoring package of the project studied above. Modeling costs were determined and broken down by ship. The earliest ship required all the initial hull and frame definition and most of the structural work: thus, it was much more expensive.

The database was then modified for the next two ships due in for deck mounted and hull mounted foundations. The total cost of completing the package, composed of five UWP, was \$18,900. For the seven ships which will be overhauled at PSNS in this class. the cost of a UWP is \$540

## COST ESTIMATE

### MODELING:

<u>VESSEL</u>	<u>#OPERATORS</u>	<u>#MAN-HOURS (MH)</u>	<u>COST (\$35/MH)</u>
ship 1	5	2,800	98,000
ship 2	3	600	21,000
Ship 3	3	480	16,000
		<hr/>	
Total		3,880	135,800

### SHORING PACKAGE COST:

% of Model Cost:	5/60 <sup>^</sup> X (2,800+ 600)	= 284 (\$35) = \$9,920
Planning Cost	2 X (32MH) <sup>^^</sup>	= 64 (\$35) = \$2,240
CAD Time	160 <sup>^^^</sup>	= 160 (\$35) = \$5,600
Eng. Support:	20% X 160	= 32 (\$35) = \$1,120

Total 540 MH \$18,900\*

\*Spreading the cost over the series of seven ships the price becomes \$2700 per package, \$540 dollars per unit work procedure.

<sup>^</sup>Sixty unit work guides are expected to be completed to support Ship 2 foundation installation. Five unit work guides were needed to support the shoring package.

<sup>^^</sup>Four days of planning by **two** people were necessary to prepare the shoring work package.

<sup>^^^</sup>The CAD operator took 20 days to complete the shoring package. Twenty percent of that time was also accompanied by engineering support,

TABLE 1

The cost of preparing the first work package, a shoring package which will be used on seven ships in series, cost approximately \$2700. It is anticipated to eliminate over 2,000 MH of rework which was required on the previous overhaul due to problems caused by warping from insufficient shoring.

(Table 1). A C&L project developed a task specific, system-oriented work instruction which did not cross key-ops or SWLIN'S. The estimated cost for a single work instruction was between \$4,000-\$5,000.

Several other as-yet undocumented savings also serve to illustrate the dramatic impact that ZORO can have on construction methods. The best example to date is a foundation which required a five week installation started 28 weeks into the overhaul. The foundation contained work from two ship-alts, and required approximately 40 holes drilled and tapped, as well as machining on board. The foundation sits along the hull behind one stantion and was located close to a major hull cut. The foundation was assembled and machined to tolerance in the structural shop, painted, and transported to the drydock. The riggers began loading the foundation at 9:30, the first tack welds were struck shortly before 11:30. The foundation was completed and welded to the deck in two shifts. For the next ship, the outboard holes will be drilled in shop to further expedite its completion.

This evolution is a direct result of the OPG studying composite drawings of the zone, interacting, and developing a work package for fabrication and installation.

Deck-mounted foundations often have very fine flatness tolerances. In the past, PSNS has machined all such foundations to ensure flatness. However, using controlled welding, the jobs can be completed much faster and do not require the restoration that is required with a mill. One set of three foundations was chosen to experiment with controlled welding to achieve a 0.015" tolerance for each and 0.030" tolerance between each other. Using a machinist level and declivity bars, the foundations were tacked to within 0.002" tolerance and welded to 0.007" tolerance of each other. The welding required more time than the usual quick weld procedure, in anticipation of machining.

As a result of the success of the controlled welding project, similar foundation pads are being examined to take advantage of this faster and less costly procedure. One ship-alt onboard

involves the installation of fifty 2x2 pads. Currently, a Liaison Action Request is being prepared for the EPY to allow for the installation of four bed-plates as an alternative to the pads. If approved and successful, the time required to complete the ship-alt may be reduced as much as two months.

Machining is not funded until the lead shop requests the funding when the foundation is in place. Since no machining was actually funded, what is shown on the MIS is a greater expenditure of manhours for the shipfitter, even though the cost of placing the mill onboard and the 2-3 days for the men to machine would have occurred. Still, the job closed underexpended, but a significant savings is left unrecorded in the official record.

Finally, the drawings from which all work is performed are in a constant state of flux as corrections are made, mistakes discovered, and updates of changes for numerous reasons cause additions and deletions. By creating 3-D models and constantly updating the database from ANDC'S and new revisions, most designed-in errors are being caught before any fabrication is begun. Over 60 corrections, both minor and major, have been discovered for the current projects' class of ships. This does not include numerous clarifications which were necessary to interpret correctly what was required for completion of the ship-alt.

More extensive results will not be available for several months due to the length of key-ops remaining open and the difficulty of translating MIS information into statistical evaluations of zoned and packaged work.

#### CONCLUSIONS AND RECOMMENDATIONS

Zone Outfitting in Repair and Overhaul is a powerful planning system that, as the project indicators show, has potential for dramatic impact to meet the criteria detailed in this paper, and accomplished the tasks given to C&L by the Navy. The Outfit Planning Group uses the experience of both production and design to improve production techniques and methods and facilitates their development and integration. Packaging work by zone optimizes production fabrication and installation, while minimizing rework. Sequencing optimizes installation time and manning to accomplish work. The unit work procedure eliminates the need for the mechanic to plan his work from scratch and coordinate haphazardly the integration of his work with other mechanics.

Adjustments to the Management Information System will allow the implementation of a flexible management sys-

tem where funding, packaging, sequencing, and scheduling can be accomplished independently, allowing Planner-men to more effectively plan and accomplish work and foremen and upper level managers to progress and facilitate the jobs for which they are responsible. In addition, accurate cost accounting, accuracy control programs, manning visibility and requirements, and corporate memory are supported by these changes.

The Philadelphia Naval Shipyard has already completed a significant planning effort for hull expansion of tanks and voids and an auxiliary machinery room in the aircraft carrier KITTYHAWK in accordance with the same zone/stage approach featured by ZORO.

There are several influences which could help the ZORO program develop faster (thus saving more money, more quickly). The first is the support of management. Although the number of supporters at PSNS has steadily grown, further support is necessary. ZORO requires increased up-front money to plan the work in detail. It is important for managers to realize that once the initial investment is made, savings will continue for the life of the ship. The Navy needs to encourage that this investment be made, and the database that will develop must be distributed freely through the Naval shipyards.

The present CAD system is a serious deterrent to the speed in which models can be created and work graphics generated. Graphics created and stored on the system are not portable to more modern, much faster systems. It is strongly recommended that another CAD system be integrated into the Naval shipyards. Numerous studies indicate the significant increase in productivity with small increments of computer response time. The CAD system's response time is presently measured in minutes, while comparable operations on other systems are in seconds or fractions thereof. This has impact on productivity, efficiency of personnel use, and seriously affects the morale of the operators.

Continued cooperation between all the Naval shipyards, NAVSEA, and C&L and increased involvement by Naval shipyards in the NSRP are essential to effectively coordinate and objectively evaluate progress and future direction.

This approach to planning and packaging work for mechanics drives Engineering to design for producibility through the coordination and experience gained by committing themselves to group technology. In this way Engineering designs a producible product that is efficiently and effectively constructed by Production. The UWP facilitates the

integration of ZORO. Their use will cause real and virtual work flows to emerge for most work so as to eliminate much of the greatest single loss in any individual enterprise, people waiting for work. Once implemented, hundreds of millions of government dollars can be saved.

Moreover, the time required to accomplish an overhaul will be reduced. This is a military requirement. This is accomplished by consolidating planning work with CAD and eliminating repetition. With careful sequencing, rework is eliminated and production manhour expenditures minimized. The system provides for feedback which will quickly integrate improvements. ZORO will allow PSNS to once again become a modern, highly efficient Naval facility.

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#### FOOTNOTES

- [1] Government regulation includes the use of material bid, constant manning policy, and management and labor of short term naval officers and ship's force.
- [2] Outfit Planning, Maritime Administration. National Shipbuilding Research Program, Seattle, c. 1979. Product Work Breakdown Structure, Maritime Administration. National Shipbuilding Research Program, Seattle, C. 1980 (Rev. 1982). Design for Zone outfitting, Maritime Administration, National Shipbuilding Research Program, Seattle, C. 1983.
- [3] Moen, Dennis, "Application of Zone Logic and Outfit Planning Concepts to Modernization and Repair of U.S. Navy Ships". Journal of Ship Production Vol. 1, November 1985, p. 245.  
Kjerulf, Shel, "Unit Work Guide for Zone Outfitting in Repair and Overhaul", Draft, February 1986.
- [4] Coopers and Lybrand, Management Analysis of the Navy Industrial Fund Program. Shipyard Review Report Draft, August 1985.
- [5] Ernie Ellsworth of Portsmouth Naval Shipyard reported the distribution of key-ops (work packages) by their size as released by Planning and Estimating for the overhaul of the SSN 690. The majority of 5,432 key-ops. 61%, each contained more than 1,000 manhours. 23% contained between 10,000 and 52,000 manhours. In contrast, most of IHI work packages were about 160 manhours 10 years ago. They are almost down to 40 manhours in size. Toyota is now down to 4 manhours.
- [6] Product Work Breakdown Structure, Maritime Administration, National Shipbuilding Research Program, Seattle, c. 1980 (rev. 1982). Flexible Production Scheduling System, Maritime Administration, National Shipbuilding Research Program, Seattle, c. 1986.
- [7] The Expanded Planning Yard is a NAVSEA program which has assigned particular classes of ships to a central organization, one single shipyard. That shipyard is responsible for incorporating any new design changes into classes of vessels, updating drawings for the class, and having an onsite production representative in the overhaul yard to expedite any engineering resolutions required.
- [8] At this time, ANDC do not always reflect the actual change on the revision, but steps are being taken to bring the percentage to a higher level.
- [9] Kjerulf, Shel. "Unit Work Guide for Zone Outfitting in Repair and Overhaul", Draft, February 1986.
- [10] Pipe Piece Family Manufacturing, Maritime Administration, National Shipbuilding Research Program, Seattle, c. 1982.
- [11] Product Oriented Safety and Health Management, Maritime Administration, National Shipbuilding Research Program, Seattle, c. 1986.
- [12] Quality Assurance (QA) checks can also be carried out at the completion of any phase of work. QA checks COULD be supported by the same UWG graphics, simplifying verification and problem reporting. This method of checking by zone in stages is being incorporated into the tank inspection and repair project at PSNS, specifically for defining the scope of work, sequencing repair and painting -- to minimize rework.
- [13] Analytical Quality Circles, National Shipbuilding Research Program, September 1986.
- [14] Storch, Richard, "Accuracy Control Variation-Merging Equations: A Case Study of Their Applications in U.S. Shipyards". Journal of Ship Production, vol. 1. May 1985. pp. 135-144.

- [15] Preliminary Study of cost Effectiveness and Schedule Enhancement of Work Packaging (Unit work Guide) C.M. Murphy, Puget Sound Naval Shipyard. Code 383.13. 21 August 1986.
- [16] Memorandum Serial 383/1147-86 on the subject of cost-benefit analysis of outfit planning.
- [17] Ibid.

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